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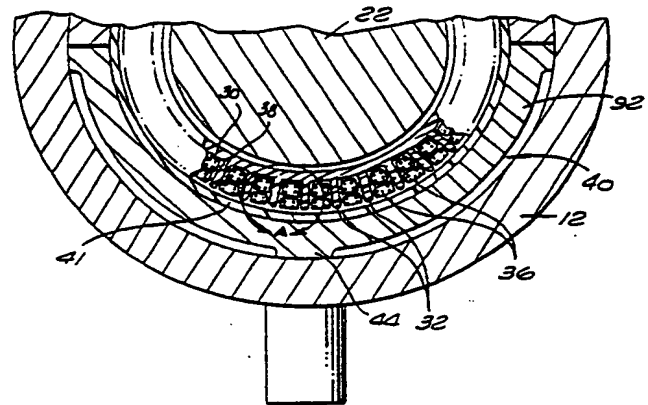
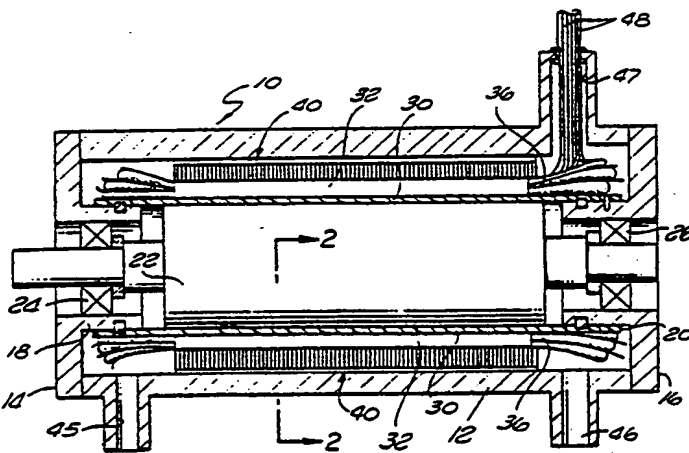
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(21) International Application Number: PCT/US90/04033 (22) International Filing Date: 18 July 1990 (18.07.90) (30) Priority data: 383,395 20 July 1989 (20.07.89) US (71) Applicant: ALLIED-SIGNAL INC. [US/US]; Law Department (C.A. McNally), P.O. Box 2245R, Morristown, NJ 07962-2245 (US). (72) Inventors: DENK, Joseph ; 428 8th Street, Manhattan Beach, CA 90266 (US). MESCHER, Donald, G. ; 21202 Berendo Avenue, Torrance, CA 90502 (US).	(74) Agent: MASSUNG, Howard, G.; Allied-Signal Inc., Law Department (C.A. McNally), P.O. Box 2245R, Morristown, NJ 07962-2245 (US). (81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent)*, DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent). Published <i>With international search report.</i>	

(54) Title: TOOTHLESS STATOR CONSTRUCTION FOR ELECTRICAL MACHINES



(57) Abstract

A stator construction for a permanent magnet rotor electrical machine (10) eliminates ferromagnetic teeth customarily used and incorporates a winding support (30) made of non-magnetizable, non-conductive material and having radially outwardly extending support fins (32) to support the stator windings (36). The windings (36) are formed of very many strands of fully transposed and insulated fine wire and are continued to the outside of the stator as lead wires (48). Windings (36) for a plurality of different phases are carried in the slots between the fins (32) and insulation strips (38) are provided which separate the phase windings (36) in the slots and which extend beyond the fins (32) to provide insulation between the end turns of the different phase windings (36). To aid in assembly a flux collector (40) which is formed of many laminations (42) and which is generally cylindrical surrounding the windings (36), is split into two half cylindrical parts. A cylindrical insulating layer (41) is interposed between the windings (36) and the flux collector (40). A housing (12) surrounding the stator includes connections (45, 46) to permit flow of a liquid or gas cooling medium through and past the stator windings (36).

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TOOTHLESS STATOR CONSTRUCTION FOR ELECTRICAL MACHINESBACKGROUND OF THE INVENTION

Field of the Invention - The present invention relates generally to the construction and configuration of a stator for electrical machines including both motors and generators, and more particularly to an improved stator construction utilizing a stator core in the form of a cylindrical ring lacking inwardly projecting teeth made of a magnetizable material, with the windings of the stator being supported by a support structure made of non-magnetizable material effectively increasing the diameter of the magnetic air gap, the support structure and windings being enclosed in a concentrically arranged cylindrical flux collector of magnetic material, thereby providing a suitable stator structure for use with high magnetic energy permanent magnet rotors.

In the design and construction of permanent magnet machines, there are two considerations which dictate the design of an improved permanent magnet machine having great appeal to potential purchasers. These two factors are, first, the desire to minimize the cost of the machine, or to provide the most machine for the least money, and secondly to increase machine efficiency while reducing machine size by utilizing the ever increasing energy product permanent magnets.

In application Serial No. 107,150 (common assignee) a stator construction is described which is relatively inexpensive to produce and which eliminates the usual T-shaped teeth extending radially inwardly. It may be appreciated that winding the stator windings onto the T-shaped teeth of the stator core is a labor intensive, and hence expensive, process.

In recent years, high energy product permanent magnets representing significant energy increases over

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previously known permanent magnets have become available. For example, samarium cobalt permanent magnets having an energy product of 27 mega-gauss-oersted (MGO) have recently become available. In addition, neodymium-iron-
5 boron magnets have recently become available which have an energy product of 35 MGO, and it appears that in the near future an energy product of at least 45 MGO will be achievable by advanced permanent magnets.

A rotor making the maximum use of high energy
10 product permanent magnets is disclosed in Assignee's United States Patent No. 4,667,123 issued May 19, 1987, entitled "Two Pole Permanent Magnet Rotor Construction for Toothless Stator Electrical Machines", which patent specification is hereby incorporated herein by reference.

15 Theoretically, the use of such high energy product permanent magnets should permit increasingly smaller machines to be built which will be capable of supplying increasingly high power outputs. However, for a particular power output a smaller machine would have
20 approximately the same amount of losses as a larger machine, and since its size is smaller the losses per volume of machine would be higher, resulting in a high watts loss density.

Such a high watts loss density would make direct
25 winding cooling virtually mandatory in order to allow the smaller machine to operate on a continuous basis. The stator describe in application S.N. 107,150 does include provision for effective cooling by suitable liquids or gasses so that the high energy product permanent magnets
30 may be used effectively it eliminates the teeth previously utilized in stator cores, and instead uses a winding support structure made of non-magnetizable material in a cylindrical configuration with a plurality of radially outwardly extending, longitudinal support
35 fins installed thereon, the support fins als being made of non-magnetizable material and pr ferably manufactured integrally with the cylindrical p rtion.

The copper windings ar installed in the areas

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between adjacent support fins on the winding support structure. Since the support fins and the winding support structure need not carry magnetic flux, they can be relatively thin, thereby maximizing the slot area in which the stator windings may be installed around the winding support structure. Since the support fins extend radially outwardly unlike the T-shaped teeth of a conventional stator core, the stator windings may be prewound on a form and easily dropped into the slots between the support fins. Also, the cylindrical portion of the winding support lends itself well to the creation of a bore seal and a channel through which a suitable liquid or gas coolant may be circulated.

SUMMARY OF THE INVENTION

The above described structure which appears in copending application S.N. 107,150, now U.S. Patent No. 4,852,245, although providing a motor with satisfactory operation, proved to be somewhat more twice consuming to assemble than desirable. Applicants' have evolved a number of structural modifications which have contributed substantially to ease of assembly, hence lowered production costs. One problem area concerned placing the assembled stator structure within the cylindrical flux collector wherein the insulation on the stator winding and leads tended to be sufficiently bulky that it was difficult to get the stator assembly with leads and insulation through the cylindrical flux collector. This laminated structure has now been split into two half cylindrical units, with each lamination now being a semi-circular plate. The plates are now bonded together by means of a flexible adhesive or laser welded on the outside edges. It has been found that the very small additional air gap between the half-cylindrical sections created no operational problems.

It was also found that the fine stranded wire used in the stator windings could effectively be extended to

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be used as lead wires, thus eliminating the internal connections between stator windings and lead wires. In previous practice the lead wires were separately connected to the stator windings and separate insulation layers were wrapped around each lead wire, an arrangement which was both bulky and time consuming. A significant improvement made was in the configuration of insulation strips between the stator windings, which insulation is required since each slot between support fins carries windings to more than one phase. By forming these insulation strips in the form of channels with integral strips extending substantially beyond the length of the stator fins, these strips became available to separate and insulate the end turn extensions of the various phases. The cumulative effect of these changes was to significantly reduce assembly time, hence cost, and to improve reliability because of the elimination of a number of separate small parts and hand operations.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional view of a motor assembly according to our invention;

Figure 2 is a cross-sectional view taken through line 2-2 of Figure 1;

Figure 2A is an enlarged portion of Figure 2 showing additional detail of the insulation between phase windings in the slots;

Figure 2B is a plan view of a pair of single half circular laminations of which the flux collector of Figures 1 and 2 is formed;

Figure 3 is a plan view of an insulation strip shown in section in Figure 2A;

Figure 4 is a plan view of the opposite side of the insulation strip of Figure 3;

Figure 5 is a partial perspective view of a portion of the motor of Figure 1, showing the end turn extensions

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of the various phase windings separately wrapped with insulation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to Figures 1 and 2 an electrical machine 10 is illustrated which has a housing 12. The housing 12 is essentially cylindrical, and has two end bells 14, 16, each of which includes smaller concentric cylindrical bearing support areas 18, 20, respectively, located in their centers. The assembly consisting of the housing 12 and the end bells 14, 16 is sealed. A permanent magnet rotor 22 is supported within the housing 12 on bearings 24, 26, which are mounted in the cylindrical bearing support areas 18, 20, respectively.

A winding support structure 30 is illustrated in Figures 1 and 2, and is essentially cylindrical, with a plurality of longitudinally extending support fins 32 extending radially outwardly from the cylindrical portion of the winding support structure 30, with slot areas located between adjacent support fins 32. In the preferred embodiment illustrated in the figures, the winding support structure 30 has thirty-six support fins 32 mounted thereon, and hence thirty-six slot areas located between the support fins 32. It should be noted that the number of slot areas may vary as in conventional stators. The winding support structure 30 is made of non-magnetizable material, typically a high temperature engineering plastic such as polyamide-imide, with the support fins 32 and the cylindrical portion of the winding support structure manufactured integrally.

It may be noted from Figure 1 that the support fins 32 are longitudinally mounted on the cylindrical portion of the winding support structure 30 intermediate the two ends, with portions at both ends of the cylindrical portion of the winding support structure 30 not carrying the support fins 32. Hence, the cylindrical portion of

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the winding support structure 30 is somewhat longer than the support fins 32, and extends from the support fins at both ends of the winding support structure 30. The ends of the winding support structure 30 not carrying the support fins 32 are where the interconnections between the portions of the stator windings 36 lying in the slot areas between the support fins 32 are made and where the lead wires are carried.

The stator windings 36 may be prefabricated on forms, and then laid into the slot areas between the support fins 32 on the winding support structure 30. The stator windings 36 will typically include two conductors installed into each slot area, each of which conductors may have multiple turns. Since the two sets of conductors installed into each slot are different phases, they are separated by insulating strips 38, as shown. (Fig. 2A) Both sides of strips 38 are shown in Figs. 3 and 4. The insulation strips 38 extend beyond the ends of the support fins 32 and are wrapped around the end turns of the stator windings 36 to insulate the various phase windings from each other as shown in Figure 5.

The stator windings 36, as stated above, are of substantially smaller diameter wire than in previous stator designs. For example, in a small 200 watt machine each of the conductors may, for example, be made up of 28 fully transposed and insulated strands of #39 AWG wire. As another example, consider a large 5M watt machine which in each conductor may, for example, be made up of 2,580 fully transposed and insulated strands of #31 AWG wire. As stated above, the purpose of using such fine fully transposed wire is that eddy currents and circulating currents are greatly reduced by using smaller size wires, an important consideration since all of the flux from the rotor will cut the wire in slot areas in a toothless stator design. Note also that the stator windings 36 are shown in schematic rather than actual form in Figures 1, 2, and 2A.

Once the stator windings 36 have been wound and are

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mounted in the slot areas around the winding support structure 30, a flux collector 40 made of magnetizable material such as electrical steel may be installed around the outer periphery of the winding support structure 30 containing the stator windings 36. Since the flux collector 40 is made of magnetizable material which is typically conductive, a cylindrical insulating liner 41 must be installed between the inner diameter of the flux collector 40 and the outer diameter of the winding support structure 30 carrying the stator windings 36. It is important to note that since the winding support structure 30 is a non-conductor, the only insulators necessary are the insulating strips 38 and the insulating liner 41. The stator windings 36 need not be impregnated with varnish, and therefore may easily be cooled by flowing coolant through the stator windings 36.

The flux collector 40 is preferably formed of a pair of half cylindrical members made up of a plurality of generally half circular flux collector ring laminations 42 shown in plan view in Figure 2B. As assembled each flux collector lamination 42 is paired with another to form a thin cylindrical lamination with four raised portions 44 arranged around its outer periphery. The raised portions 44 function to support the flux collector ring 40 inside the housing 12 while allowing coolant to flow between the flux collector ring 40 and the housing 12. Note that in smaller machines a ferrite core may be substituted for the laminated construction of the flux collector ring 40.

The assembled split flux collector 40 is installed over the winding support structure 30 carrying the stator windings 36 with the insulating liner 41 therebetween, and the resulting assembly is then mounted inside the housing 12 as illustrated in Figures 1 and 2. Note that the inner diameter of the ends of the cylindrical portions of the winding support structure 30 are mounted in interference fit fashion around the outer diameter of the cylindrical bearing support areas 18, 20 at the ends of

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the housing. A chamber or channel is thereby formed between the interior of the housing 12 and the outer surfaces of the winding support structure 30 through which coolant may be flowed. The housing has a coolant inlet channel 45 at one end of the housing, and a coolant outlet channel 46 at the other end of the housing. It may therefore be appreciated that coolant may be flowed into the housing 12 through the coolant inlet channel 45, through the unvarnished stator windings 36 and around the flux collector ring 40, and out of the housing 12 through the coolant outlet channel 46 to cool the stator assembly of the machine 10. An additional aperture 47 in the housing 12 is used to bring the winding leads 48 from the stator windings 36 through the housing 12, which aperture 47 is sealed to prevent coolant leaks.

An electrical machine built according to the present invention includes the operation of and cost advantages described in copending application S.N. 107,150 while effecting further cost reductions by enhancing cost of assembly while at the same time providing some improvements in long term reliability. The improvements in insulation structure also aid and enhance cooling by reducing bulk, particularly near the coolant outlet passage. The teachings of the present invention are obviously useful for machines of different sizes, power capability and phase structure as will be appreciated by those skilled in the art.

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What is claimed is:

1. A stator for a permanent magnet electrical machine (10), comprising

a winding support structure (30) made of non-magnetizable, non-conductive material, said winding support structure (30) having a cylindrical portion with a plurality of longitudinal support fins (32) which extend radially outwardly from said cylindrical portion, said support fins (32) providing therebetween a plurality of slot areas;

stator windings (36) laid into said slot areas between said support fins (32) including conductors formed of fully transposed and insulated fine stranded wire to minimize eddy currents and circulating currents, said conductors serving also as lead wires to said stator windings (36); and

a substantially cylindrical flux collector ring (40) made of ferromagnetic material and mounted around the outer periphery of said winding support structure (30), said flux collector ring (40) being split longitudinally into two half cylindrical sections, said flux collector ring (40) thereby extending around the outermost edges of said support fins (32).

2. A stator as defined in Claim 1, wherein said split flux collector ring (40) comprises a plurality of semi-circular flux collector laminations (42).

3. A stator as defined in Claim 2, wherein said laminations (42) are bonded together.

4. A stator as defined in Claim 1, wherein said flux collector ring (40) includes end laminations of a non-magnetizable, non-conductive material.

5. A stator as defined in Claim 1, wherein said stator windings (36) have insulation strips (38) installed

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between different phase conductors installed in the same slot areas, said insulation strips (38) including elongated center sections formed into channels located in said slot areas and end extensions extending beyond said slot areas for insulating and separating end turn extensions of different phase windings of said stator windings (36).

6. A method of making a stator for a permanent magnet electrical machine (10), comprising:
10 providing a winding support structure (30) made of non-magnetizable, non-conductive material, said winding support structure (30) having a cylindrical portion with a plurality of longitudinal support fins (32) which extend radially outwardly from said cylindrical portion, said
15 support fins (32) providing therebetween a plurality of slot areas;

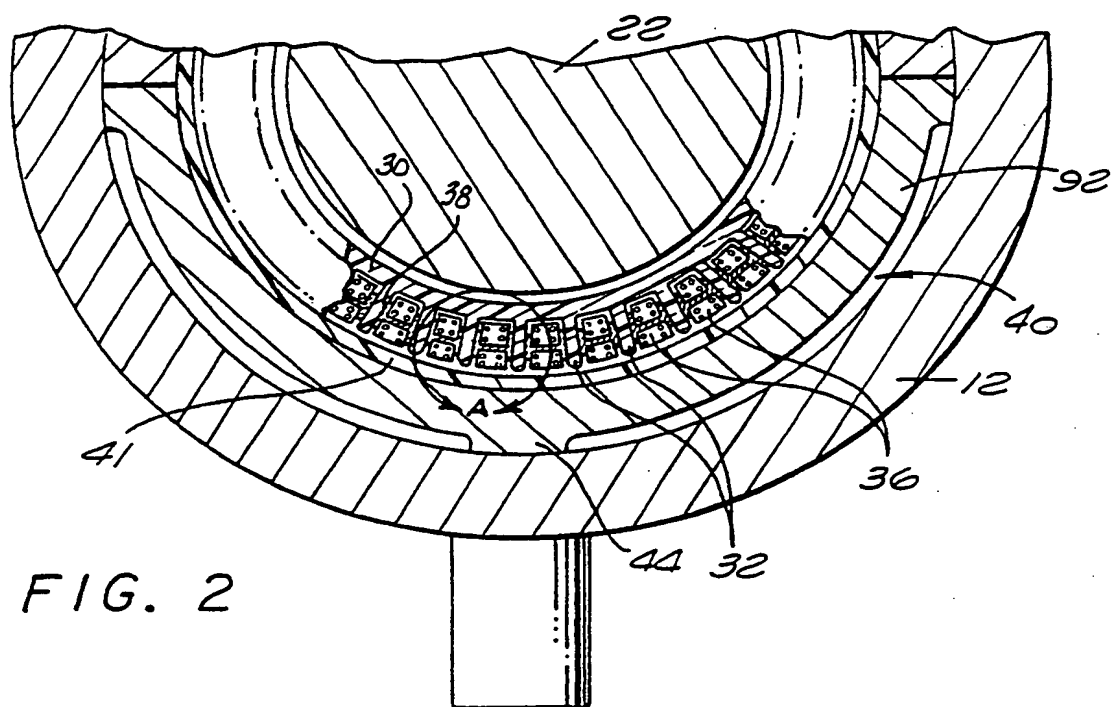
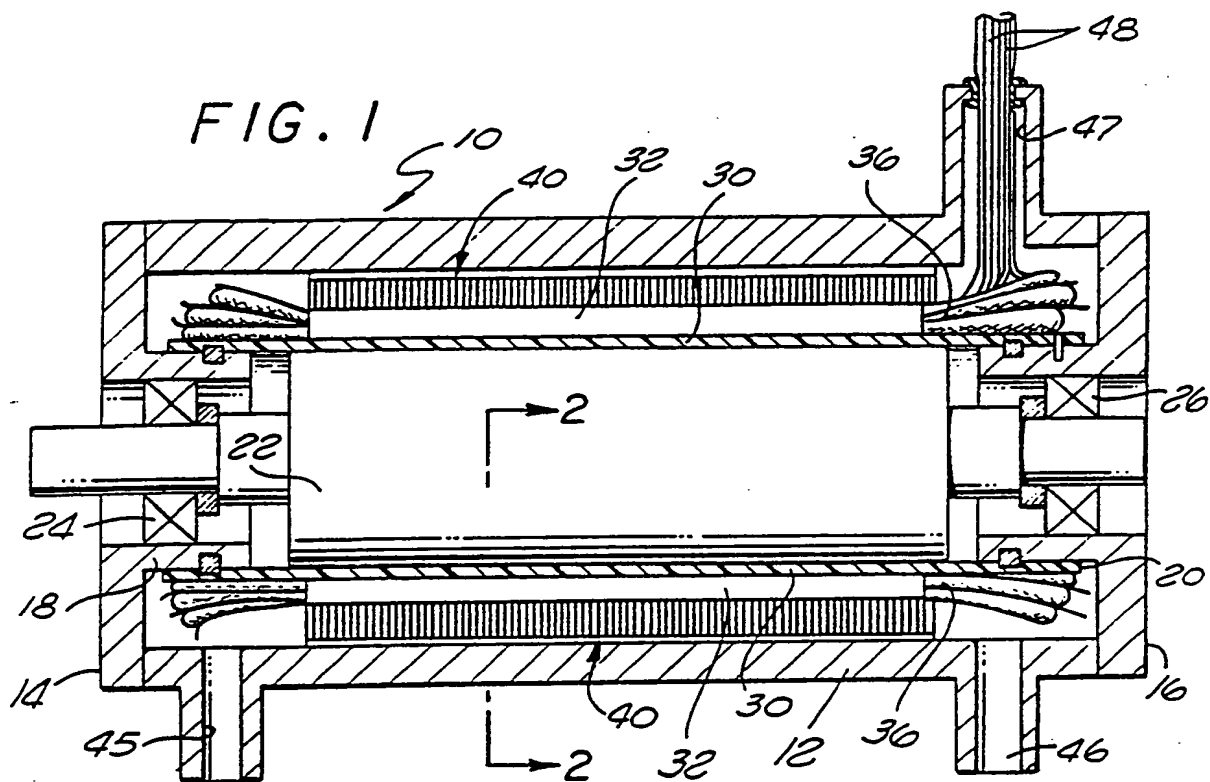
installing insulated and transposed finely stranded stator windings (36) into said slot areas between said support fins (32) and continuing said windings without
20 internal connections to serve as lead wires;

forming a plurality of semi-circular laminations (42) of ferromagnetic material into two half-cylindrical flux collector members; and

mounting said flux collector members around the
25 outer periphery of said winding support structure (30) forming a flux collector ring (40), said collector ring (40) thereby extending around the outer edges of said support fins (32).

7. A method of making a stator for a permanent
30 magnet electrical machine (10) as defined in Claim 6 including arranging said windings with different phase windings (36) in the same slot areas,

installing insulation strips (38) between said different phase conductors, said strips including
35 extensions extending axially beyond said slot areas, and arranging said extensions around the end turns of said windings (36) to separate the end turns of said different phase windings (36).



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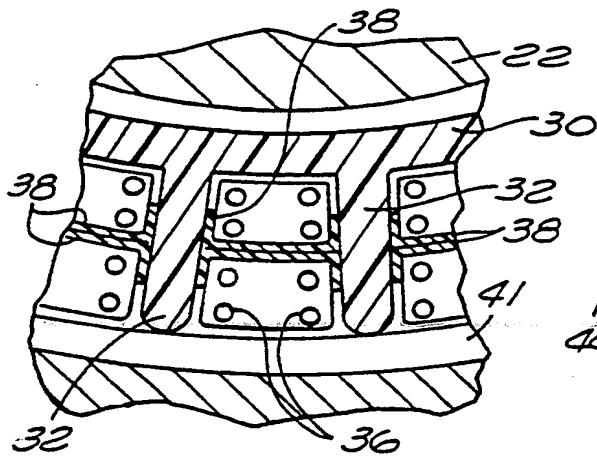


FIG. 2A

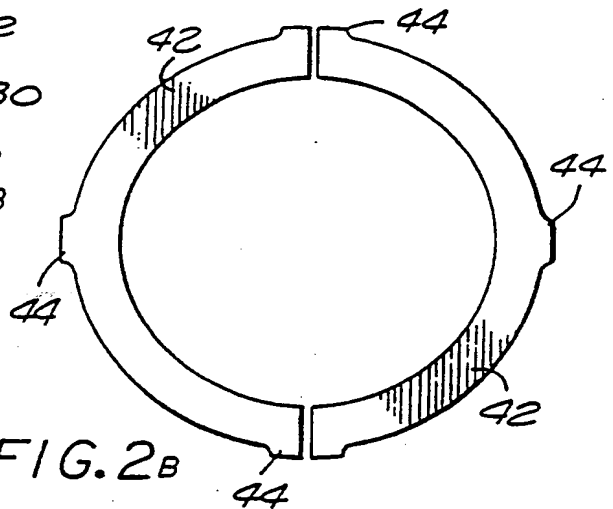


FIG. 2B

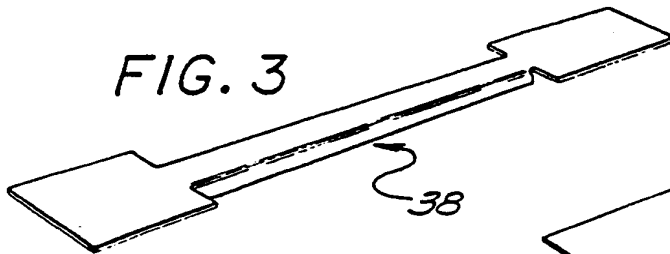


FIG. 3

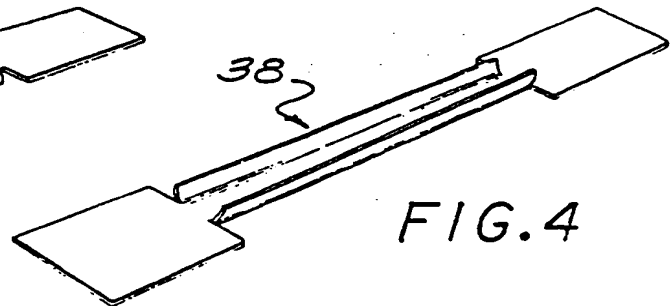


FIG. 4

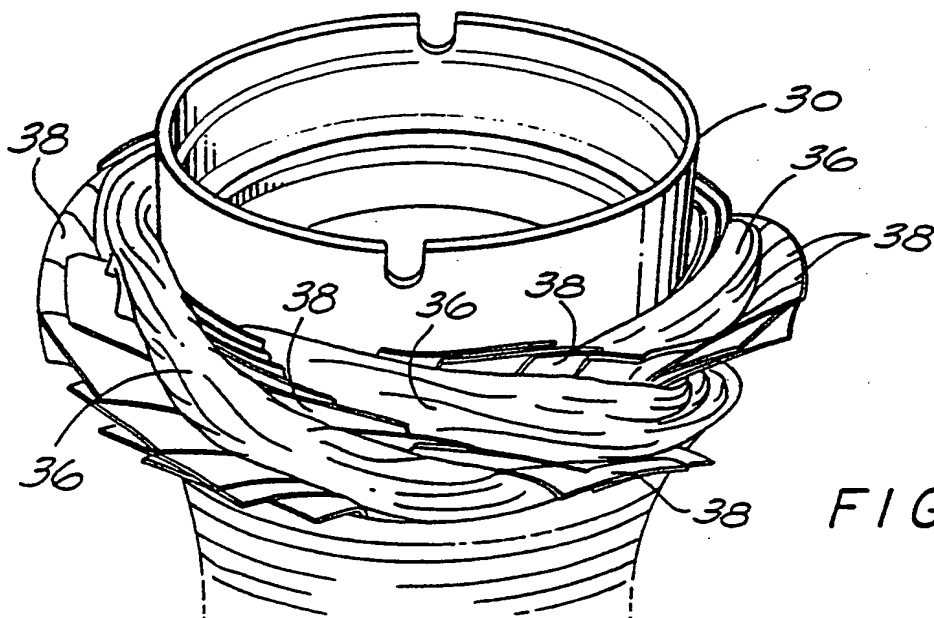


FIG. 5

SUBSTITUTE SHEET

International Application No.

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)⁶

Int.Cl. 5 H02K3/47 ; H02K5/22 ; H02K3/32

Minimum Documentation Searched⁷

Classification Symbols

H02K

**Documentation Searched other than Minimum Documentation
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Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
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Y

FR,A,1198777 (SIGMA-LUTIN) 09 December 1959
see page 1, right-hand column, lines 8 - 18;
figure

1. 6.

Y

US,A,3875435 (FLETCHER ET AL) 01 April 1975
see column 3, line 56 - column 4, line 2;
figures 1, 2.

1. 6.

A

DE,A,1613202 (LICENTIA) 23 April 1970
see page 2, line 8 - page 5, line 5; figures
1-4.

1-3. 6.

A

US,A,1957380 (BARLOW) 01 May 1934
see page 1, line 60 - page 2, line 3; figures
1-9.

1-4.

A

DE,C,943137 (SIEMENS-SCHUCKERT) 09 May 1956
see page 2, lines 49 - 66; figures 4, 5.

5. 7.

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^o Special categories of cited documents : ¹⁰

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	EP,A,0225132 (GARRETT) 10 June 1987 see column 9, line 43 - column 10, line 54; figures 1-11. (cited in the application) ---	1, 6.

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US-A-3875435	01-04-75	None	
DE-A-1613202	23-04-70	None	
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		US-A- 4908347	13-03-90

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